A new multi-dimensional general relativistic neutrino hydrodynamics code for core-collapse supernovae. Method and code tests in spherical symmetry

B. Mueller (1), H.-Th. Janka (1), H. Dimmelmeier (2) ((1) MPI Astrophysik, Garching; (2) Aristotle Univ. of Thessaloniki)

(Submitted on 27 Jan 2010)

We present a new general relativistic (GR) code for hydrodynamic supernova simulations with neutrino transport in spherical and azimuthal symmetry (1D/2D). The code is a combination of t CoCoNuT hydro module, which is a Riemann-solver based, high-resolution shock-capturing method, and the three-flavor, energy-dependent neutrino transport scheme VERTEX. VERTEX integrates the neutrino moment equations with a variable Eddington factor closure computed from a model Boltzmann equation and uses the ray-by-ray plus approximation in 2D, assuming th neutrino distribution to be axially symmetric around the radial direction, and thus the neutrino flux to be radial. Our spacetime treatment employs the ADM 3+1 formalism with the conformal flatness condition for the spatial three-metric. This approach is exact in 1D and has been shown to yield very accurate results also for rotational stellar collapse. We introduce new formulation of the energy equation to improve total energy conservation in relativistic and Newtonian hydro simulations with Eulerian finite-volume codes. Moreover, a modified version of the VERTEX scheme is developed that simultaneously conserves energy and lepton number with better accuracy and higher numerical stability. To verify our code, we conduct a series of tests, including detailed comparison with published 1D results for stellar core collapse. Long-time simulations of proto-neutron star cooling over several seconds both demonstrate the robustness of the new CoCoNuT-VERTEX code and show the approximate treatment of GR effects by means of an effective gravitational potential as in PROMETHEUS-VERTEX to be remarkably accurate in 1D. (abridged)

Comments:	36 pages, 19 eps figures; submitted to ApJS
Subjects:	**Solar and Stellar Astrophysics (astro-ph.SR)**; General Relativity and Quantum Cosmology (gr-qc)
Cite as:	**arXiv:1001.4841v1 [astro-ph.SR]**

Submission history

From: Bernhard Müller [view email]
[v1] Wed, 27 Jan 2010 20:04:34 GMT (375kb)